Variability of the Surface Circulation and the Surface Temperature/Chlorophyll Fields in the Adriatic Sea

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LONG-TERM GOALS

To contribute to the understanding of the dynamics of marginal seas such as the Adriatic by collecting and interpreting observations of currents and water mass properties (e.g., temperature, salinity, chlorophyll concentration). In particular, to study the variability of the surface velocity and temperature/chlorophyll fields in the Adriatic at the meso-, seasonal and interannual scales and to assess the impact of the wind forcing and fresh water runoffs.

OBJECTIVES

1) To assess the quality of historical drifter data sets in the Adriatic Sea, i.e., to intercompare the water-following capabilities of the various drifters, to apply adequate corrections and to merge these data sets to obtain a useful multi-year drifter database.

2) To use this multi-year drifter database, along with satellite images, to describe the spatial characteristics and the temporal variability of the surface circulation, the sea surface temperature (SST) and the surface chlorophyll concentration in the global Adriatic basin, from meso- to interannual scales. To investigate some aspects of the response of the surface circulation and SST/chlorophyll to atmospheric (e.g., winds) and boundary (e.g., river runoffs) forcings.

3) To assess the level of agreement between modeled and observed near-surface Lagrangian circulation in the Adriatic through comparisons of numerically simulated and observed drifter trajectories. The goal is to gain knowledge to improve future strategies of drifter deployments in coastal environments, and to better interpret Lagrangian and satellite observations.

APPROACH

1) The analysis and interpretation of historical Adriatic surface drifter data sets collected between 1990 and 1999 by various organizations, mostly by the SACLANT Undersea Research Centre (SACLANTCEN), by the Naval Oceanographic Office (NAVOCEANO) and by the Naval Postgraduate School (NPS). First, a quantitative comparison study of the water-following capabilities of the drifter systems used is performed. Second, Eulerian and Lagrangian statistics of the Adriatic surface circulation and SST are computed, and horizontal fluxes of momentum and heat are estimated.

2) The use of satellite images concurrently with the drifter data to describe the variability of the surface currents, SST and surface chlorophyll fields in the Adriatic Sea. AVHRR images archived by SACLANTCEN and processed by the Satellite Oceanography Laboratory of the University of Hawaii (Dr. P. Flament) are used to study the SST variability during periods of large drifter concentration, i.e., 1995, 1997 and 1998. SeaWiFS images downloaded from the Goddard DAAC and processed at the Tiburon Remote Sensing Laboratory of San Francisco State University (Dr. N. Garfield) are utilized to create maps of surface chlorophyll concentration for fall 1997 and the entire year 1998.

3) The comparison, in a quantitative sense, of the trajectories of the historical Adriatic drifters to numerically simulated tracks computed using the Dartmouth finite-element model (Drs. B. Cushman-Roisin and C. Naimie, Dartmouth College).

WORK COMPLETED

1) The data from about 200 Adriatic surface drifters between 1990 and 1999 were acquired from various institutions (mostly NPS, SACLANTCEN and NAVOCEANO). The data were quality controlled, reduced, edited for obvious outliers and processed to create low-pass filtered time series sampled uniformly at 6-hour intervals. Technical details about the drifter systems and the drifter data processing, along with graphical representations of the data, have been assembled in a dedicated world wide web page (NPS, 1999) and on a CD-ROM that will be available at the end of the year.

Eulerian and Lagrangian statistics were estimated from the drifter data (Poulain, 1999). These statistics include: Eulerian maps of mean flow, velocity variance, mean and eddy kinetic energy, divergence and vorticity; seasonal maps of mean flow and velocity variance; estimates of diffusivity, Lagrangian space and time scales, etc.

2) More than 1000 AVHRR images of the Adriatic were processed for the periods May-Nov. 1995 and Aug.-Dec. 1997. The processing included registration, navigation, calculation of SST and cloud masking. The 1995 SST maps were made available on a CD-ROM (Anonymous, 1998). A statistical comparison between contemporaneous SST data from drifters and from satellite images was performed using the 1995 data. The satellite SST images were corrected and analyzed to provide image composites over 3-day, weekly and monthly periods (Vogt, 1998).

Over 100 SeaWiFS images were processed using the SeaDAS software to produce color-coded chlorophyll maps of the Adriatic Sea for fall 1997 and winter 1998 (Mauri and Poulain, 1999).

A qualitative description of the surface mesoscale structures in the Adriatic and of their associated temporal variability was done by superimposing drifter trajectory segments on the satellite SST/chlorophyll images (Vogt, 1999; Mauri and Poulain, 1999).

3) I went to Dartmouth College in September 1999 to begin the comparison between observed drifter tracks and numerically simulated trajectories. Because of the unusually good grouping of drifters along the eastern coast during the summer of 1995, this region at that period was selected for a preliminary comparison. Orographically steered NORAPS winds (Horton et al., 1997) were used to force the model.

RESULTS

1) The surface drifters revealed four re-circulation cells in the general cyclonic circulation in the Adriatic, persisting for the four seasons of the year (Fig. 1). The cells in the central and southern basins are controlled by the topography of the Jabuka and south Adriatic pits, respectively, as is expected from theoretical arguments (Carnevale et al., 1999). Recirculation around the south Adriatic pit is stronger in winter and spring. The other two cells more to the north are dominated by the river Po and Bora wind influences and their variability is less seasonal. The seasonal signal of the Eastern Adriatic Current in the southern basin is striking, with a maximum in winter and fall. In contrast, the strong Western Adriatic Current all along the Italian Peninsula does not show significant seasonal variability, with the possible exception of a maximum in fall. The latter season has the most intense circulation cells in the central and southern basin, which appear to have merged in a single circulation pattern.

Velocity fluctuations around the mean circulation of Fig.1 are maximum in the strong coastal currents with major principal axes oriented along the coastline/isobaths. Their energy levels are maximum in summer and fall.

Diffusivities of about 1-2 x 10^7 cm^2s^{-1} and Lagrangian integral time scales near 1-2 days have been estimated by removing a constant Eulerian mean field similar to the ones shown in Fig.1 and by computing dispersion statistics using the velocity residuals.

2) The joint use of drifter data and satellite (SST/chlorophyll) images provides remarkable information on the structure and variability of the mesoscale circulation in the Adriatic Sea. There is often a good agreement between the drifter motions and the structure and evolution of the SST/chlorophyll features. An example is shown in Fig. 2 for the southern Adriatic in winter 1998. The maximum in chlorophyll concentration near the center of the basin is related to the weak upwelling associated with the mean cyclonic circulation around it and/or to vertical mixing in the upper water column (intermediate water formation). Instabilities or meandering motions formed at the edge of the maximum are well represented by the drifter motions.

Other aspects of the surface dynamics in the Adriatic, such as upwelling events off the eastern coast, were also described using the drifter and satellite observations (Vogt, 1999).

IMPACT/APPLICATION

The scientific impact of this project will be to increase our understanding of the Adriatic Sea dynamics and of the major forcing mechanisms. Future application could be the assimilation of the drifter data into numerical models in the framework of the anticipated Mediterranean Forecasting System (MFSPP, 1999).

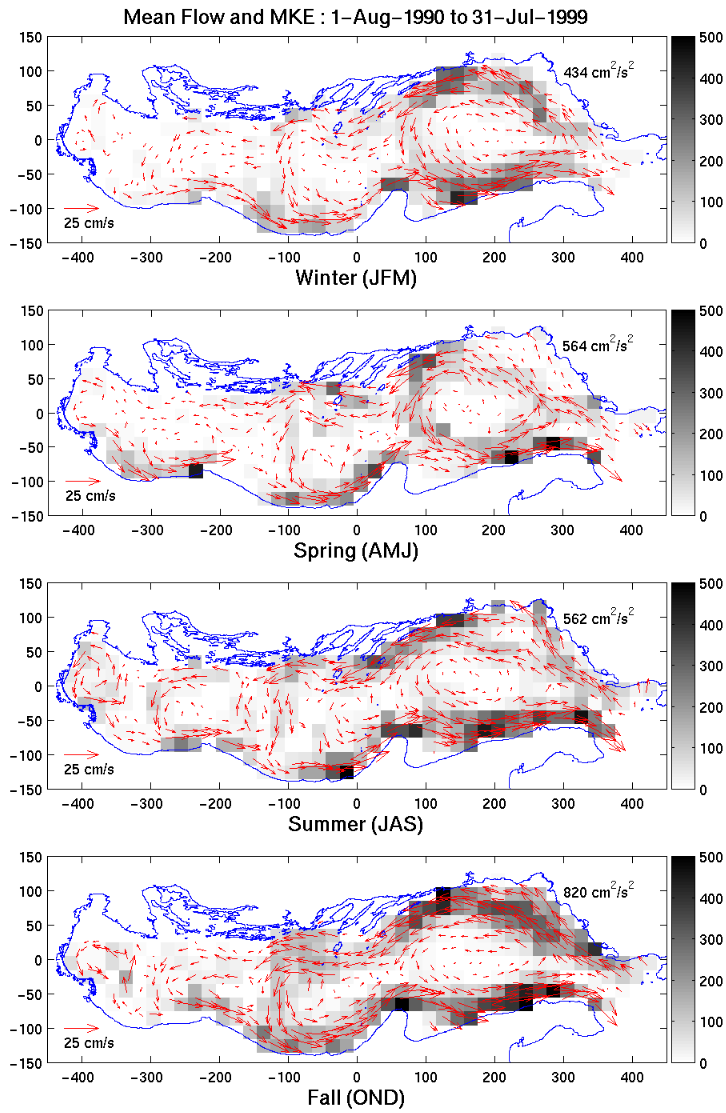

Fig. 1. Mean flow and mean kinetic energy (gray shades, units : cm^2/s^2) derived from the drifter data in the Adriatic between Aug. 1990 and July 1999. The maximum energy is posted near the top-right corner for each season. The Adriatic Sea has been rotated by 45° in the anticlockwise direction.

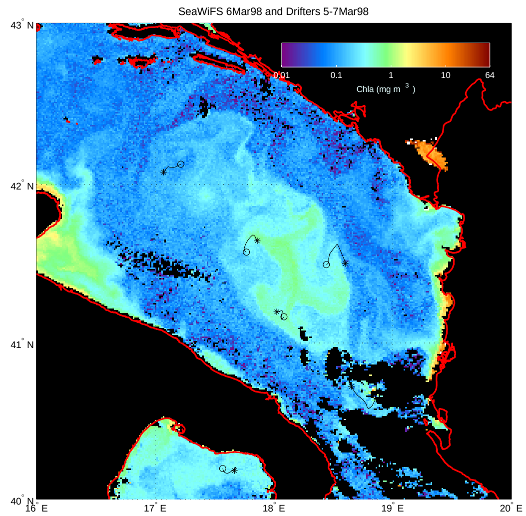

Fig. 2. SeaWiFS chlorophyll concentration map of the southern Adriatic on 6 March 1998. Three-day long drifter trajectories centered on the day of the image are superimposed. Star and open circle symbols represent the start and end points, respectively.

TRANSITIONS

Graphical representations of the drifter data were made available on the world wide web (NPS, 1999) in quasi-real time and could be used by anyone interested in the Adriatic surface currents and temperature (e.g., for rescue, military and fisheries operations). The drifter SST data were also directly distributed onto the Global Telecommunication System (GTS) in order to be assimilated into models for weather forecasting.

This program proves the usefulness of the drifters that NAVOCEANO has been (and is currently) using to obtain environmental observations during sea operations, to quantitatively estimate surface currents.

It is planned to assimilate the drifter data (velocities and SST) into various numerical models of the circulation in the Adriatic to improve forecasting skills (Horton et al., 1997; Cushman-Roisin and Naimie, 1999; MFSPP, 1999).

RELATED PROJECTS

Other ONR Projects: Drs. B. Cushman-Roisin and C. Naimie (Dartmouth College) are funded to develop a comprehensive, finite-element model of the Adriatic Sea. Comparison studies between model results and the drifter data are in progress. Drs. A. Griffa , T. Ozgokmen and A. Mariano (RSMAS, University of Miami) and I are funded to develop new methodologies to use Lagrangian data to enhance mesoscale prediction skills. Applications have been performed using the Adriatic drifter data.

Italian PRISMA Project: Hydrographic/ADCP data in the western Adriatic and HF radar observations off Ancona, Italy, as part of the Italian project "Programma di RIcerca e Sperimentazione per il Mare Adriatico" (PRISMA-2a, 1999) will be used with the drifter data to study the Adriatic circulation. Collaborators are Drs. Gacic, Artegiani and Dallaporta.

MATER Project: The drifter data will be used by European scientists (Dr. Gacic and others) working on the deep-water formation mechanisms in the southern Adriatic in the framework of the MATER program (MATER, 1999).

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